April 1984

DCIEM No. 84-C-17

MEASUREMENT OF THE BODY COMPOSITION OF CANADIAN FORCES FEMALE PERSONNEL

D.G. Bell

K.M. Cox

Defence and Civil Institute of Environmental Medicine
1133 Sheppard Avenue West, P.O. Box 2000
Downsview, Ontario, Canada M3M 3B9

DEPARTMENT OF NATIONAL DEFENCE - CANADA

TABLE OF CONTENTS

	Page
ABSTRACT	1
INTRODUCTION	2
METHODS	2
Subjects	2
Procedure	2
Anthropometry	2
Height and Weight	3
Skinfolds	3
Circumferences	3
Diameters	3
Densitometry	3
Residual Volume	4
Calculation of Derived Values	4
The Standard Test of Fitness Equations	5
Equation for Female Subjects	5
Statistical Treatment of Data	5
RESULTS AND DISCUSSION	5
The STF Assessment of Body Composition	5
Other Anthropometric Assessments of Body Composition	6
STF vs Other Anthropometric Predictions of Body Composition	8
CONCLUSION	9
RECOMMENDATION	9
REFERENCES	10

LIST OF TABLES

Page

TABLE 1 - Physical characteristics of the subject (mean + S.D.) 5

TABLE 2 - Body composition determined from UWW and STF procedures (mean ± S.D.) for CF female personnel 6

TABLE 3 - Correlation (r) between two techniques (STF and UWW) for measuring body density and % BF of CF females 6

TABLE 4 - Mean ± standard deviation for skinfold thicknesses, limb circumferences and bone diameters 7

TABLE 5 - Multiple correlation coefficients for the predictions of body density from all anthropometric variables ... 8

ABSTRACT

The purpose of this study was to evaluate the procedures described in the Health and Welfare Canada Standard Test of Fitness (STF) for determining body density and percent body fat from four skinfold measures. Underwater weighing (UWW) and anthropometric measures (height, weight, nine skinfold thicknesses, nine body and limb circumferences and seven bone diameters) were measured on 66 female CF volunteers, age 19 to 56. Body density values determined by UWW were compared to values predicted from the sum of four skinfolds, (triceps, biceps, subscapular and suprailiac), using equations developed by Durnin and Womersley (7) as outlined in the STF. The correlations between density determined by these two methods differed among age groups; the highest was 0.87 (for the total sample) and the lowest was 0.78 (for the 40-56 year old group).

Other combinations of variables were tested to see if density could be predicted more accurately than by the STF procedure. Using optimal combinations of three variables, correlations between predicted density and density determined by UWW ranged from 0.85 to 0.91. Since these values are the same as those produced using the STF procedures, it was concluded that the STF method of estimating body density and percent body fat is adequate, at least for the population tested.

INTRODUCTION

An assessment of body composition using the Standard Test of Fitness (STF) (1) procedures for a sample Canadian Forces (CF) male population was conducted in late 1981 and early 1982, and reported on by Bell and Cox (2). That study reported that the STF method tended to overestimate percent body fat (% BF) in CF male personnel and that other anthropometric measures would give a better estimate of body fat. This paper reports on a similar study conducted in June 1982 which assessed the body composition of a sample CF female population using the same STF procedures. Again other anthropometric measures were taken from which age and sex specific equations could be produced for predicting density for comparison with measured density from underwater weighing (UWW) conducted in the laboratory setting.

METHODS

Subjects

Sixty-six CF females from National Defence Headquarters participated in this study. They ranged in age from 19 to 56 years. Physical characteristics of the subjects are presented in Table 1.

Procedure

Each subject, wearing only a light-weight bathing suit, reported to the testing area. Subjects were instructed to refrain from eating or smoking for at least three hours prior to the test and to wear no jewellery or bathing cap. Testing was conducted at an indoor swimming pool.

Anthropometric measurements were done prior to the subject's immersion in water. Measurements included height, weight, nine skinfold thicknesses, nine body and limb circumferences and seven bone diameters. Underwater weighing was conducted immediately following the anthropometry. The same observer took all anthropometric measurements, and residual lung volumes were determined on the same day.

Anthropometry

Most anthropometric measures were carried out according to standard procedures, as outlined by Behnke & Wilmore (3). Exceptions to these procedures are noted. All limb circumferences, bone diameters and skinfold measurements were taken on the right side of the body. Two readings were taken at each site, and the mean value was recorded. A third measurement was taken if the first two showed a notable discrepancy (greater than 0.4 mm for skinfolds, 0.3 cm for circumferences, or 0.2 cm for diameters) and the closest two measures were then used to determine the mean.

Height and Weight

Body weight, to the nearest 0.1 kg, and standing height, to the nearest 0.5 cm, were measured using a standard medical weigh scale. Subjects wore light-weight bathing suits and were barefoot.

Skinfolds

Skinfold thicknesses were measured to the nearest 0.1 mm using Harpenden calipers. The procedures outlined in the STF operational manual were used to measure the triceps, biceps, subscapular and suprailiac skinfolds. The five additional sites measured were the abdomen (vertical fold, 2 cm to the right of the umbilicus), medial thigh (longitudinal fold at the point of the thickest deposit of fat, with the leg supported and flexed at the knee), anterior thigh, medial calf (vertical fold at the level of maximal circumference, with the leg supported and flexed at the knee), and posterior calf.

Circumferences

Body and limb circumferences were measured to the nearest 0.1 cm using a cloth tape, placed horizontally or at right angles to the length of the body segment. The subject stood relaxed with heels together. Sites measured were the neck, biceps (flexed), forearm (maximum girth, with arm extended), wrist (minimum girth), chest (above the breast tissue), waist (at the level of minimum abdominal width, or "abdomen I" as defined by Behnke & Wilmore (3)), hips (maximum girth), thigh (just below the gluteal fold), and calf (maximum girth).

Diameters

Bone diameters were measured to the nearest 0.1 cm using a Siber Hegner anthropometer and a Siber Hegner spreading caliper. Measurements were taken of the elbow, wrist, knee, ankle, biacromial, biiliac, and bitrochanter diameters. The subject was seated for the first four measures, and standing for the remaining three.

Densitometry

Underwater weighing was conducted in an indoor swimming pool with a water depth of approximately 1.2 m. A beam-like apparatus was constructed to hold a Chatillon 9-kg scale in a position where an observer could accurately read the scale, yet the subject could be suspended about one metre away from the side of the pool. A nylon sling-type harness was attached to the scale by a nylon line.

The subject entered the pool and was instructed to squeeze out any air bubbles trapped in the hair and bathing suit. She then put on a 3.8 kg. diving weight belt to ensure complete submersion. When the

observer was confident that all air had been expelled from the lungs and the subject was not touching the pool floor or wall, a reading was taken from the scale. This procedure was repeated six to ten times until three similar readings (within 20 g) had been obtained. Water temperature in degrees Celsius was recorded after each subject had been weighed. The average of the three best readings, rather than the highest score, was recorded as the true underwater weight. According to Katch & Katch (4), this results in a more dependable and consistent individual score, and is the statistical procedure of choice when UWW is done separately from residual lung volume (RV) determinations.

Residual Volume

Residual lung volume (RV) was determined by the single breath nitrogen washout technique, using a Hewlett-Packard Pulmonary Function System (45804S) and standard test criteria. The subject was in a standing positon for all tests.

For those subjects unable to perform a valid nitrogen washout test after three attempts, RV was predicted from a regression equation using height and age (5). Of the 66 subjects, 13 (20%) were unable to perform an acceptable nitrogen washout test.

Calculation of Derived Values

Density, % BF and lean body weight (LBW) were calculated from the data collected for each subject as shown below.

1. Body Density
   Body density was computed from the following formula:
   Density = Wt/([Wt-Ww/Dw]-[RV + 0.1])
   Where:
   Wt = weight in air (kg)
   Ww = weight in water (kg)
   Dw = density of water corrected for temperature
   RV = residual lung volume (1), with 0.1 l added to allow for gas trapped in the gastrointestinal tract.

2. Percent Body Fat
   Percent body fat from UWW was calculated using the formula of Siri (6):

   % BF = (4.95/Density-4.5) x 100

3. Lean Body Weight
   Lean body weight was calculated from body weight and % BF using the following formula:

   LBW (kg) = Wt - (Wt x %BF)

The Standard Test of Fitness Equations

The equations to determine density from skinfolds adopted by the STF were developed by Durnin and Womersley (7). Equations particular to each subject's sex and age group were used and are as follows:

Equation for Female Subjects:

Aged 16 - 19	Density = 1.1549 - 0.0678 (log sum of 4 skinfolds)
Aged 20 - 29	Density = 1.1599 - 0.0717 (log sum of 4 skinfolds)
Aged 30 - 39	Density = 1.1423 - 0.0632 (log sum of 4 skinfolds)
Aged 40 - 49	Density = 1.1333 - 0.0612 (log sum of 4 skinfolds)
Aged 50 +	Density = 1.1339 - 0.0645 (log sum of 4 skinfolds)

Measurements taken at the biceps, triceps, subscapular and suprailiac sites were used for the sum of the four skinfold thicknesses. This estimation of body density was transformed to % BF using the equation of Siri (6), as previously described.

Satistical Treatment of Data

Subjects were considered as a total group and in three subgroups based on age. The 16 to 19 and the 50 + age group were combined with the 20 to 29 and 40 to 49 group, respectively, for analysis because of insufficient numbers. The density for the individuals in these categories were still predicted from the appropriate STF equation metioned above. Means and standard deviations were calculated for all anthropometric measures. A paired t-test was used to measure the difference between the density means determined from UWW and the STF method (8). For each group, a stepwise multiple linear regression analysis was used to produce the optimum combination of 1, 2, 3, 4, and 5 independent variables for the prediction of body density. The multiple correlation coefficient (r) associated with each combination indicated which measures best predicted density as determined by UWW.

RESULTS AND DISCUSSION

The STF Assessment of Body Composition

The physical characteristics of the subjects are presented in Table 1.

Table 1: Physical characteristics of the subjects (mean + S.D.)

Parameter	All Ages (n = 66)	19-29 yr (n = 25)	30-39 yr (n = 24)	40-56 yr (n = 17)
Age (yrs)	33 ± 9	24 ± 3	33 ± 2	46 ± 4
Height (cm)	163 ± 5	162 ± 5	163 ± 6	165 ± 5
Weight (kg)	64 ± 11	60 ± 7	64 ± 12	70 ± 11

Table 2 presents a summary of the mean values for body density, % BF and LBW for all groups. Both body weight (Table 1) and % BF are higher in the older age groups, while density is reduced and LBW shows little change. This suggests that weight gained with age is a result of increased body fat, rather than a gain in LBW, which is in accordance with the results of the companion study on males (2).

Table 2: Body composition determined from UWW and STF procedures (mean ± S.D.) for CF female personnel

	All Ages (n = 66)	19-29 yr (n = 25)	30-39 yr (n = 24)	40-56 yr (n = 17)
Density (gm/cc)*	1.033± .016	1.040±0.01	1.035±0.018	1.020±.010
% BF *	29.2±7.2	25.9±4.4	28.2±8.2	35.4±4.8
% BF **	29.6±6.3	25.9±4.0	29.2±6.1	35.4±4.6
LBW*	44.8±5.5	44.1±4.1	45.3±6.2	45.0±6.2

* Determined from UWW
** Determined from the STF procedures

These data indicate that for all age groups, % BF determined from the STF procedures is not significantly different from those determined by UWW. For females, the correlation coefficients between the two techniques for determining % BF and density (Table 3) were high and statistically significant for the total group ($r = 0.87$, $p < 0.01$) and for all the sub-groups, ($r = 0.84$ to 0.78, $p < 0.01$). These results are in contrast with the earlier findings reported for males in the CF (2) suggesting that the determination of % BF from skinfolds may be more accurate for females than for males.

Table 3: Correlations (r) between two techniques (STF and UWW) for measuring body density and % BF of CF females.

	All Ages	19-29 yr	30-39 yr	40-56 yr
Density	0.87	0.83	0.83	0.78
%BF	0.87	0.83	0.84	0.78

Other Anthropometric Assessments of Body Composition

Table 4 presents the mean values for the nine skinfolds, nine circumferences and seven bone diameters for the total group and the three sub-groups. Although all measurements appear to increase with age, the abdomen, triceps and thigh skinfolds and abdominal circumference show the greatest increases. This suggests that it may be important to incorporate measurements from these areas into equations to estimate % BF.

Table 4: Mean ± standard deviation for skinfold thicknesses, limb circumferences and bone diameters.

Variable	All Subjects (n = 66)	Age 19-29 (n = 25)	Age 30-39 (n = 24)	Age 40-59 (n = 17)	Short Form
Skinfolds (mm)					
Triceps	19 ± 7	16 ± 4	18 ± 8	23 ± 7	tri
Biceps	8 ± 4	6 ± 3	8 ± 4	11 ± 5	bi
Subscapular	15 ± 8	12 ± 4	16 ± 9	18 ± 9	sub
Suprailiac	17 ± 9	15 ± 5	18 ± 12	21 ± 8	sup
Abdomen	21 ± 9	18 ± 6	20 ± 10	28 ± 9	ab
Thigh (medial)	24 ± 9	22 ± 7	24 ± 10	29 ± 9	th(m)
Thigh (anterior)	32 ± 11	30 ± 9	32 ± 11	36 ± 11	th(a)
Calf (medial)	20 ± 8	18 ± 6	20 ± 9	23 ± 8	ca(m)
Calf (posterior)	23 ± 9	22 ± 7	22 ± 9	25 ± 9	ca(a)
Circumferences (cm)					
Neck	32 ± 2	32 ± 1	33 ± 2	33 ± 2	nkcir
Biceps	30 ± 3	28 ± 2	30 ± 3	32 ± 3	bicir
Forearm	25 ± 2	24 ± 1	25 ± 2	26 ± 2	focir
Wrist	15 ± 1	15 ± 1	15 ± 1	16 ± 1	wrcir
Chest	87 ± 6	85 ± 4	87 ± 6	90 ± 6	chcir
Abdomen	72 ± 8	69 ± 5	72 ± 9	78 ± 8	abcir
Hip	99 ± 7	95 ± 5	98 ± 8	103 ± 7	hipcir
Thigh	59 ± 5	57 ± 4	49 ± 6	62 ± 5	thcir
Calf	36 ± 3	36 ± 2	36 ± 3	37 ± 3	cacir
Diameters (cm)					
Elbow	6.1 ± 0.3	6.0 ± 0.3	6.1 ± 0.3	6.3 ± 0.4	elbdia
Wrist	5.0 ± 0.3	4.9 ± 0.2	5.0 ± 0.3	5.1 ± 0.3	wrdia
Knee	8.7 ± 0.5	8.6 ± 0.4	8.7 ± 0.5	9.0 ± 0.6	kndia
Ankle	6.6 ± 0.3	6.6 ± 0.3	6.6 ± 0.4	6.7 ± 0.3	ankdia
Biacromial	36 ± 2	36 ± 1	36 ± 2	37 ± 2	biaciad
Biiliac	29 ± 2	28 ± 2	29 ± 2	30 ± 2	biildia
Bitrochanter	33 ± 2	32 ± 2	33 ± 2	34 ± 2	bitrdia

Table 5 shows the multiple correlation coefficients (r) and the standard error of the estimate (SEE) for the prediction of body density using a combination of one to five anthropometric variables. The data shows that the three age groups differ in which single or combined variables gave the best prediction of body density. For all groups, the measurement of a single variable produces significant correlations with density ($r = 0.77$ to 0.85, $p < 0.01$). As more variables are added, the r and SEE increase and decrease, respectively, reflecting the increasing accuracy of prediction. However, the use of more than three variables produces little improvement in the predictive equation.

STF vs Other Anthropometric Predictions of Body Composition

The STF method using four skinfold measurements to predict body density produced correlations ranging from 0.78 to 0.87, (Table 3). When the optimal combinations of three anthropometric variables were used to predict density specific for this sample and its subgroups, correlations ranged from 0.85 to 0.91 (Table 5). These values are slightly better than those produced using the STF method. This suggests that although the STF method is adequate for evaluating density and % BF in this CF females, more accurate estimates can be obtained by using other anthropometric variables specific to the sample.

Table 5: Multiple correlation coefficients for the prediction of body density* from all anthropometric variables

Group	Independent Variables	r **	SEE
All ages	tri, age, ab, hipcir, ht	0.87	0.0080
(n = 66)	tri, age, ab, th(a)	0.86	0.0083
	tri, age, ab	0.85	0.0085
	tri, age	0.84	0.0088
	tri	0.81	0.0093
Ages 19-29	tri, ht, abcir, age, nkcir	0.93	0.0041
(n = 25)	tri, ht, abcir, age	0.91	0.0043
	tri, ht, abcir	0.90	0.0045
	tri, sup	0.82	0.0058
	tri	0.78	0.0065
Ages 30-39	ab, sup, th(a), tri, wrcir	0.94	0.0070
(n = 24)	ab, sup, th(a), tri	0.93	0.0076
	ab, sup, th(a)	0.90	0.0085
	th(m), ab	0.87	0.0093
	th(m)	0.85	0.0100
Ages 40-59	hipcir, ht, sub, nkcir, wt	0.94	0.0043
(n = 17)	hipcir, ht, sub, nkcir	0.92	0.0048
	hipcir, ht, sub	0.91	0.0049
	hipcir, ht	0.86	0.0056
	ab	0.77	0.0069

* Density as determined from UWW
** $p < 0.01$ for all results

CONCLUSION

Body density values estimated from four skinfold measurements using the STF procedures correlate well with values determined by UWW for all age groups; r = 0.78 to 0.87, $p<0.01$. Substituting other anthropometric variables (other skinfolds, limb circumferences, bone diameters) does not improve the correlation suficiently to justify the increase in complexity; r = 0.85 to 0.91, p 0.01. Hence, it is concluded that the basic STF method, using the sum of four skinfolds, is adequate for predicting body density or % BF in a population similar to that tested in this study.

RECOMMENDATION

Although the sample tested in this sutdy is rather small, the overall STF method is based on a larger sample. Therefore, it is recommended that the STF method be adopted for predicting % BF and body density in CF female personnel.

REFERENCES

1. Minister of State, Fitness and Amateur Sport. Standard Test of Fitness: Operations Manual. Health and Welfare Canada, Fitness and Amateur Sport Branch, Ottawa, 1979.

2. Bell, D.G. and Cox, K.M. Measurement of the Body Composition of Canadian Forces Male Personnel. DCIEM TC No. 84-C-05.

3. Behnke, A.R. and Wilmore, J.H. Evaluation and Regulation of Body Build and Composition. Prentice-Hall, Englewood Cliffs, N.J., 1974.

4. Katch, F.I. and Katch, V.L. Measurement and prediction errors in body composition assessment and the search for the perfect prediction equation. Research Quarterly. 51: 249-260, 1980.

5. Bates, D.V., Macklem, P.T., Christie, R.V. et al. Respiratory Function in Disease. W.B. Saunders Co., Philadelphia, pp 93-94, 1971.

6. Siri, W.B., Body composition from fluid spaces and density: Analysis of methods. Techniques for Measuring Body Composition, National Academy of Sciences National Research Council, Washington, D.C., pp 223-244, 1961.

7. Durnin, J.V.G.A. and Womersley, J. Body fat assessed from total body density and its estimation from skinfold thickness: Measurements on 481 men and women aged 16 to 72 years. British Journal of Nutrition. 32: 77-97, 1974.

8. Klugh, H.E. Statistics: The Essentials for Research. John Wiley & Sons, Inc., New York, 1970.